THE EUMETSAT SATELLITE PROGRAMMES
AN OVERVIEW FROM NOW TO THE FUTURE

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EUMETSAT

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from EUMETSAT and its partners
Current EUMETSAT satellite fleet – Extrapolated end 2016

**METOP -A and -B**
(LOW-EARTH, SUN – SYNCHRONOUS ORBIT)

EUMETSAT POLAR SYSTEM/INITIAL JOINT POLAR SYSTEM

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**Sentinel -3a**
(LOW-EARTH, SUN-SYNCHRONOUS ORBIT)

Copernicus Global Marine and Land Environment Mission Operated by EUMETSAT

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**JASON-2, -3**
(LOW-EARTH, 63° INCL. NON SYNCHRONOUS ORBIT)

OCEAN SURFACE TOPOGRAPHY MISSION

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**METEOSAT SECOND GENERATION -9, -10, -11**
(GEOSTATIONARY ORBIT)

TWO-SATELLITE SYSTEM:
- METEOSAT-11: IN-ORBIT BACKUP
- METEOSAT-10: FULL DISK IMAGERY MISSION AT 0° (15 MN)
- METEOSAT-9: RAPID SCAN SERVICE OVER EUROPE AT 9.5°E (5 MN)

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**METEOSAT -8 (2nd GENERATION)**
(GEOSTATIONARY ORBIT)

INDIAN OCEAN DATA COVERAGE MISSION
AT 40° E (TBD June 2016)
EUMETSAT programmes overview

YEAR...
03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

Mandatory Programmes

METEOSAT FIRST GENERATION
METEOSAT-7
METEOSAT SECOND GENERATION
METEOSAT-8
METEOSAT-9
METEOSAT-10
MSG-4/METEOSAT-11

METEOSAT THIRD GENERATION
MTG-I-1: IMAGERY
MTG-S-1: SOUN丁ING
MTG-I-3: IMAGERY
MTG-I-4: IMAGERY

EUMETSAT POLAR SYSTEM (EPS)
METOP-A
METOP-B
METOP-C
METOP-10
METOP-11
METOP-12
METOP-SG-A1
METOP-SG-B1
METOP-SG-A2
METOP-SG-B2

Optional and Third Party Programmes

JASON
JASON-2
JASON-3
JASON CONTINUITY OF SERVICE (JASON-CS)
COPERNICUS
SENTINEL-3
SENTINEL-4 ON MTG-S
SENTINEL-5 ON EPS-SG

New dates
- First launch 2020
- Extended lifetime
- First Launch 2021
- Current Launch year 2020
Future programmes shape the 2020 – 2040 timeframe

MTG: Approved, under development
Sentinel-4 approved (funded by Copernicus)

EPS-SG: Approved, under development
Sentinel-5 approved (funded by Copernicus)

Jason-CS/Sentinel-6:
Approved, under development
MTG Programme – Space Segment

Twin satellite concept - based on 3-axis platforms:
- 4 geostationary imaging satellites (MTG-I)
- 2 geostationary sounding satellites (MTG-S)

MTG-I:
- Flexible Combined Imager (FCI)
- Lightning Imager Instrument (LI)
20 years of operational service

MTG-S:
- Infrared Sounder (IRS)
- Ultra-violet, Visible and Near-infrared Sounder (UVN)
15.5 years of operational service

Established through a cooperation between:

ESA
EUMETSAT
Meteosat-7 is the last
Located over
- Indian Ocean
- until end of 2016
From MVIRI on MTP to SEVIRI on MSG...
From MVI RI on MTP to SEVI RI on MSG to MTG FCI
38 years of observations and counting ....

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<table>
<thead>
<tr>
<th>'Core' channels</th>
<th>Meteosat 1\textsuperscript{st} Generation</th>
<th>Meteosat 2\textsuperscript{nd} Generation</th>
<th>Meteosat 3\textsuperscript{rd} Generation</th>
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<tbody>
<tr>
<td></td>
<td>Central wavelength (µm)</td>
<td>Width (FWHM) (µm)</td>
<td>Spatial Sampling (km)</td>
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<tr>
<td>FC-VIS 0.4</td>
<td>0.444</td>
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<td>FC-IR 7.3</td>
<td>13.4</td>
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Repeat Cycle : 30 min 15 min 10 min

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<tr>
<th>FPM</th>
<th>FPA</th>
<th>Resolution (km)</th>
<th>AHI Band #</th>
<th>Nominal Wavelength (µm)</th>
<th>ABI</th>
<th>AHI</th>
<th>AMI</th>
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<td>A1230</td>
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<td>A1330</td>
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<td>13.3</td>
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</tr>
</tbody>
</table>

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P. Griffith/HARRIS:
Met-8 super-rapid scans 2.5 min experiment

2.5 minutes
Repeat Cycle

5 minutes
Repeat Cycle

15 minutes
Repeat Cycle
Cloud Analysis Improves

Channel values and differences are ‘firmed up’ using thresholds plus supporting information such as forecast fields and physical properties. This enables decisions to be made on scene contents.
Continuation of AMVs Guaranteed!

FES, 02/09/2014, 20:45 - 03/09/2014, 19:45

RSS, 11/09/2014, 6:30 - 12/09/2014, 5:30
The LI Instrument

LI Main characteristics:
• Measurements at 777.4 nm
• Coverage close to “visible disc”
• Continuous measurements of (lightning) triggered events
• Spatial resolution ~ 4.5 km at SSP
• Integration time per frame 1 ms
• Background subtraction & event detection in on-board electronics

The baseline for the LI is a 4-Optical Chain solution:
• 4 identical optical channels with CMOS back-thinned backside illuminated detectors
• 1170 x 1000 pixels per camera

End-users (Level 2) will not see the “detector structure”
Observing lightning
Reference processor product example

“Accumulated flash area” product, integrated over 15 minutes and updated every 30 seconds
Date: 20 June 2013.
LIS Lightning Storm Climatology 1998-2006

LIS - December

LIS - June
Improved knowledge of the state of electrification of thunderstorms (weak electrification within the extended anvils) will improve aviation guidance in the vicinity of airports and en route.

Source: Kawasaki, Univ. Osaka

Source: Kawasaki, Univ. Osaka
MTG Mission: InfraRed Sounder (IRS)

- MTG-IRS will deliver unprecedented information on horizontal and vertical gradients of moisture, wind and temperature from the geostationary orbit:
  - Full Disk Sounding;
  - spatial resolution of 4 km,
  - hyperspectral soundings at 0.625 cm-1 spectral sampling in two bands:
    - Long-Wave-IR (LWIR: 700 – 1210 cm-1 ~820 spectral samples)
    - Mid-Wave-IR (MWIR: 1600 – 2175 cm-1 ~920 spectral samples)
MTG-IRS observations

time sequence of water vapour structures

simulated AMVs

Courtesy W.L. Smith
MTG-IRS and short range NWP

time sequence of water vapour structures  
model convection
The InfraRed Sounder (IRS) is based on

- an imaging interferometer with a hyperspectral resolution of 0.625 cm\(^{-1}\),
- 2 detector arrays with each 160 x 160 detectors,
- taking measurements in two bands: the Long-Wave InfraRed (LWIR, 700–1210 cm\(^{-1}\) or 14.3–8.3 µm) with 800 spectral channels and the Mid-Wave InfraRed (MWIR, 1600–2175 cm\(^{-1}\) or 6.25–4.6 µm) with 900 spectral channels,
- with a spatial resolution of 4 km,
- with a basic repeat cycle of 60 min.

The IRS will provide e.g. highly resolved vertical structures of humidity, temperature (+ boundary layer temperature profile), ozone, and wind.

MTG-IRS Instrument Characteristics

- Volume: 1.4 x 1.6 x 2.2 m\(^3\)
- Mass: 400 kg
- Power: 750 W
MTG-I RS Concept: Every 30 Minutes Europe

~ 300 stares for Full Disc Coverage
78 LAC1 + 78 LAC2 + 78 LAC3 + 79 LAC4 = 313 Dwell

~ 75 stares Local Area Coverage (LAC)
LAC-1/2/3/4 repeat cycle: 15 min including 2-3 min for calibration

MTG-I RS Operations Scenario
Simulating the Geo-IRS perspective

**True**

06-12-2002, 1200 UTC
Lifted Index [°C]

![True map 1](image1)

**GIFS/HES/IRS**

06-12-2002, 1200 UTC
Lifted Index [°C]

![GIFS/HES/IRS map 1](image2)

Red = extreme instability

06-12-2002, 1200 UTC
Radar reflectivity [dBZ]

![Radar reflectivity](image3)

06-12-2002, 1200 UTC
Lifted Index [°C]

![Lifted Index map](image4)
## Summary User Priorities on MTG Missions

<table>
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<tr>
<th>MTG Flexible Combined Imager</th>
<th>MTG Infrared Sounder</th>
<th>MTG Lightning Imager</th>
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<td>Absorbed Shortwave Radiation</td>
<td>Cloud Top Phase</td>
<td>All Sky Radiances</td>
</tr>
<tr>
<td>Active Fire Detection / Monitoring</td>
<td>Cloud Top Pressure</td>
<td>Rainfall Potential and Probability</td>
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<tr>
<td>Aerosol/Dust Detection</td>
<td>Cloud Top Temperature</td>
<td>Rainfall Rate/Multisensor QPE</td>
</tr>
<tr>
<td>Aerosol Optical Thickness</td>
<td>Cloud Type</td>
<td>Reflected Solar Radiative Flux TOA</td>
</tr>
<tr>
<td>Aerosol Particle Size</td>
<td>CO Concentration</td>
<td>Scene Analysis</td>
</tr>
<tr>
<td>All Sky Radiances</td>
<td>Convection Initiation</td>
<td>Sea &amp; Lake Ice/Age</td>
</tr>
<tr>
<td>Aircraft Icing Threat</td>
<td>Atmospheric Motion Vectors</td>
<td>Sea &amp; Lake Ice/Concentration</td>
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<td>Air Mass Analysis</td>
<td>Downward Longwave Irradiance</td>
<td>Sea &amp; Lake Ice/Displacement and Direction</td>
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<td>Atmospheric Moisture Profile</td>
<td>Downward Shortwave Irradiance</td>
<td>Sea &amp; Lake Ice/Extent and Characterization</td>
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<td>Atmospheric Temperature Profile</td>
<td>Emitted Longwave Radiative Flux TOA</td>
<td>Sea Surface Temperature</td>
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<tr>
<td>Capping Inversion Information</td>
<td>Enhanced Overshooting Top Detection</td>
<td>Snow Cover</td>
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<tr>
<td>Clear Sky Masks</td>
<td>Fire Radiative Power</td>
<td>CO Concentration</td>
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<tr>
<td>Clear Sky Radiances</td>
<td>Fire Radiative Energy</td>
<td>Surface Albedo</td>
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<tr>
<td>Clear Sky Reflectance Map</td>
<td>Flood/Standing Water</td>
<td>Surface Emissivity</td>
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<td>Climate Data Set</td>
<td>Global Instability Indices</td>
<td>Total Precipitable Water</td>
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<td>Cloud Coverage</td>
<td>High Resolution Precipitation Index</td>
<td>Total Water Content</td>
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<tr>
<td>Cloud Ice Water Path</td>
<td>Humidity Products (upper/midlevel rel. Hu)</td>
<td>Turbulence</td>
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<tr>
<td>Cloud Imagery</td>
<td>Ice Covered Land</td>
<td>Upward Longwave Radiation at Surface</td>
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<tr>
<td>Cloud Layers / Heights and Thickness</td>
<td>Land Surface (Skin) Temperature</td>
<td>Vegetation Fraction LAI</td>
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<tr>
<td>Cloud Liquid Water</td>
<td>Lightning Detection</td>
<td>Vegetation Index</td>
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<tr>
<td>Cloud Mask</td>
<td>Low Cloud and Fog</td>
<td>Visibility</td>
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<td>Cloud Optical Depth</td>
<td>Moisture Flux</td>
<td>Volcanic Ash</td>
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<td>Cloud Particle Size Distribution</td>
<td>Ozone Layers</td>
<td>Wind Divergence</td>
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<td>Cloud Top Height</td>
<td>Ozone Total</td>
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AMS 96 January 2016
Aims to involve potential operational users of MTG-IRS Level 2 products in the development of the level 2 processor.

The results of this evaluation will be used to identify limitations of the envisaged products and where possible to start mitigation actions in light of the experience with the proxy data.

The near real time demonstration project is expected to start before 3Q 2016, and will run for 6 months.

It will be based on level 2 products from IASI (on Metop-A and B) and CrIS (on NPP-1).

Besides vertical profiles for temperature and humidity and their uncertainty, and the surface temperature and its uncertainty, also the so-called scaled projected states (and the associated Observation Operator) of these two variables will be made available.
EPS Second Generation: A twin satellite system
**EPS Second Generation**

- Continuation and enhancement of service from mid morning polar orbit in 2021 – 2040
- Twin satellite in-orbit configuration:
  - **Metop-SG A**: optical imagery and sounding mission
    - Flies the Copernicus Sentinel-5 instrument
  - **Metop-SG B**: microwave imaging mission
- Two series of 3 successive satellites for 21 years of operations
- Orbit @ 09:30 LTDN (Same as Metop)
- Phasing of Sat-a and Sat-b 180°

<table>
<thead>
<tr>
<th></th>
<th><strong>Satellite a</strong></th>
<th><strong>Satellite b</strong></th>
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<tbody>
<tr>
<td>Payload</td>
<td>METImage, IASI-NG, MWS, 3MI, S-5, RO</td>
<td>SCA, MWI, ICI, ARGOS-4, RO</td>
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<tr>
<td>Launch mass</td>
<td>3661 kg</td>
<td>3339 kg</td>
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<td>Power</td>
<td>2.3 kW</td>
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<tr>
<td>P/L data rate</td>
<td>54 Mb/s</td>
<td>6.3 Mb/s</td>
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## Observation Missions

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<th>Applications Benefitting</th>
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<td>IASI-NG</td>
<td>NWP, NWC, Air Quality, CM</td>
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<td>Visible/ Infra-red Imaging</td>
<td>METimage</td>
<td>NWC, NWP, CM, Hydrology, Oceanography</td>
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<td>Microwave Sounding</td>
<td>MWS</td>
<td>NWP, NWC, CM</td>
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<td>Radio Occultation Sounding</td>
<td>RO</td>
<td>NWP, CM</td>
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<td>Nadir viewing UV/ VIS/ NIR/ SWIR Sounding</td>
<td>Sentinel 5</td>
<td>Ozone-UV, Air Quality, CM, Composition-Climate interactions</td>
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<td>3MI</td>
<td>Air Quality, CM, NWC</td>
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<td>SCA</td>
<td>NWP, NWC, Oceanography, Hydrology</td>
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<td>Microwave Imaging</td>
<td>MWI</td>
<td>NWP, NWC, Hydrology, CM, Oceanography</td>
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<tr>
<td>Ice Cloud Imaging</td>
<td>ICI</td>
<td>NWP, NWC, Hydrology, CM</td>
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</table>
Hyper-spectral infrared sounding: IASI - NG

Objectives
- Temperature/humidity profile at high vertical resolution
- Clouds, trace gases (O₃, CO, CH₄, CO₂,...)
- Sea/land/ice surface temperature
- Aerosols, Volcanic Ash

Implementation
- Development of Fourier Transform Spectrometer IASI-NG by CNES

Key performances
- spectral range: 645 – 2760 cm⁻¹
- spectral resolution: 0.25 cm⁻¹
- radiometric calibration: 0.25 K
- stability: 0.1 K
- Radiometric noise: 0.045 – 1.1 K
- pixel size: 12 km
- spatial sampling: 25 km
- cross-track scan

Breakthrough
- Doubling of radiometric and spectral resolution of IASI for the benefit of weather forecast and atmospheric composition
  - 75% more information in temperature profiling, particularly PBL
  - 30 % more information in water vapour profiling
  - Quantification of trace gases which are currently only detected
  - Vertical resolution of trace gases instead of columnar amounts only
Optical imaging

**METimage**

- **Objectives**
  - Hi-res cloud products, incl. microphysics
  - Aerosols
  - Polar AMVs
  - Vegetation, snow, fire
  - Sea/ice/land surface temperature
  - Support to sounding missions

- **Implementation**
  - Development of *METimage* by DLR

- **Key performances**
  - 20 channels: 0.443 – 13.345 µm
  - Absolute calibration: 5% (short-wave)
  - 0.5 K (long-wave)
  - Radiometric sensitivity:
    - SNR 60 – 500 (short-wave)
    - 0.05 – 0.2 K (long-wave)
  - Spatial sampling: 500 m
  - Cross-track scan

**Breakthrough**

- Far more spectral channels than AVHRR for the benefit of measuring more variables

- Higher spatial resolution (500 m):
  - More complete coverage through greater likelihood to measure surface variables in partly cloud conditions

- Better radiometric resolution for more accurate quantification of many variables
Microwave Sounding

**Objectives**
- Temperature/humidity profiles in clear and cloudy air
- Cloud liquid water total column
- Imagery: precipitation

**Implementation**
- ESA development

**Key performances**
- 24 channels: 23.8 – 229 GHz
- Absolute calibration: 0.5 K
- Radiometric noise: 0.2 – 1.6 K
- Footprint size: 17 – 40 km
- Cross-track scan

**Breakthrough**
- **Addition of a quasi-window channel at 229 GHz (recommended by ITSC-11)**
  - Cirrus cloud information giving a better humidity retrieval performance
- **Addition of sounding channels**
  - + 2 channels at 53-54 GHz
  - + 3 channels at 183.31 GHz
- More information on temperature and water vapour profiles
Scatterometry

Objectives
- ocean surface wind vectors
- soil moisture
- snow equivalent water
- sea-ice type

Implementation
- ESA development

Key performances
- C-band carrier frequency
- VV + VH polarisation
- measurement range: 4 – 40 m/s
- Radiometric resolution: 3%
- spatial resolution: 25 km
- dual swath: 550 km each

Breakthrough
- Increase of spatial resolution to 25 km
  - Better approach of coast lines
- Increase of swath width to >1100 km
  - Enhanced coverage
- Addition of VH polarisation
  - Covers higher wind speeds without saturation, will benefit observation of tropical and extra-tropical storms
Radio-Occultation

- **Objectives**
  - Refractivity profiles at high vert. resolution
  - Temperature / humidity profiles
  - PBL top and tropopause height
  - Ionospheric electron content

- **Implementation**
  - ESA development

- **Key performances**
  - tracking of GPS and Galileo satellites
  - optional: GLONASS and COMPASS
  - RO on two satellites: > 2600 occultations per day
  - bending angle accuracy: 0.5 µrad or 0.2%

---

**Breakthrough**

- **Tracking of GPS and Galileo satellites to double the number of occultation measurements**
- **Equipment of both Metop-SG satellites with RO in case of a dual satellite configuration**
UVNS Nadir Viewing

UV/VIS/ NIR/ SWIR sounding

Objectives
- Ozone profile and column
- Columns of CO$_2$, SO$_2$, NO$_2$, H$_2$O, CO, CH$_4$.
- Aerosol optical depth
- Columns of BrO, HCHO, OCHCHO

Implementation
- GMES Sentinel-5 to be embarked on Metop-SG, ESA development

Key performances
- Spectral range: 0.27 – 2.385 µm
- Spectral resolution: 0.25 – 1 nm
- Radiometric calibration: 1 – 2%
- SNR: 120 - 1500
- Spatial sampling: 7 km

Breakthrough
- Drastically increased spatial sampling (7 km) for the benefit of air quality monitoring
- Extended spectral range into the near and shortwave infrared regions to measure aerosols as well as methane and carbon monoxide in the PBL
Microwave Imaging

- Objectives of a new mission
  - precipitation and cloud products
  - water vapour profiles and imagery
  - sea-ice, snow, sea surface wind

- Implementation
  - ESA development

- Key performances
  - 18 channels: 18.7 – 183 GHz
  - dual polarisation (V, H) up to 89 GHz
  - V polarisation at higher frequencies
  - radiometric accuracy: 1 K
  - radiometric sensitivity: 0.6 – 1.2 K
  - Footprint size: 10 – 50 km
  - spatial sampling: 7 km
  - conical scan

Breakthrough: 18 channels

- Continuity of key microwave imager channels for weather forecast

- Inclusion of dedicated sounding channels (118.75 GHz)
  - Enhanced precipitation measurements through inclusion of dedicated sounding channels

- Extended suite of 183.31 GHz channels
  - water-vapour and cloud profiling
Ice Cloud Imaging

- Objectives of a new mission
  - Cloud products, in particular ice clouds
  - Snowfall detection and quantification
  - Water-vapour profiles and imagery

- Implementation
  - ESA development

- Key performances
  - 11 channels: 183 – 664 GHz
  - Single polarisation (V) for all channels
  - Dual polarisation (V, H) at 243 and 664 GHz
  - Radiometric accuracy: 1 – 1.5 K
  - Radiometric sensitivity: 0.6 – 1.9 K
  - Footprint size: 15 km
  - Spatial sampling: 7.5 km
  - Conical scan

Breakthrough: 11 channels

- Establishes operational ice-cloud imaging mission

- Support of weather forecast, hydrology, and climate monitoring
Multi-viewing multi-channel multi-polarisation Imaging

- **Objectives of a new mission**
  - Aerosol – optical thickness, particle size, type, height, absorption
  - Volcanic Ash
  - Cloud phase, height, optical depth
  - Surface albedo

- **Implementation**
  - ESA development

- **Key performances**
  - 12 channels: 0.41 – 2.13 µm
  - 3 polarisations: 0°, 60°, -60°
  - 14 views
  - Radiometric bias: 3%
  - SNR: 200
  - Spatial sampling: 4 km
  - Push-broom scan (2200 km swath)

- **Breakthrough:**
  - **Enhanced spatial sampling (4 km)**
    - Improves separation of cloudy areas
  - **12 spectral channels (9 polarised), extending into the UV and SWIR**
    - Better aerosol characterisation
  - **Higher angular resolution (14 views)**
    - Better phase function characterisation

Kaufman et al. (2002)
Observation missions are highly complementary

- Co-registration of measurements will allow to optimise the information extraction
- Synergy to be considered in payload distribution of a dual satellite configuration

Essential co-registrations
- IAS – VII – UVNS
- MWI – ICI

Desired co-registrations
- IAS – MWS
- VII – 3MI
- IAS – UVNS – 3MI
- MWI – SCA – VII
Test Data: MWI-1 HiRes
# Test Data: MWI Channels 1 - 18

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<thead>
<tr>
<th>Channel</th>
<th>Frequency (GHz)</th>
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<tbody>
<tr>
<td>MWI-1</td>
<td>18.7</td>
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<td>MWI-2</td>
<td>23.8</td>
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<tr>
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<td>52.610</td>
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<td>MWI-6</td>
<td>53.24</td>
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<td>MWI-7</td>
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<td>MWI-8</td>
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<td>MWI-9</td>
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<td>MWI-10</td>
<td>118.7503±2.10</td>
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<td>MWI-11</td>
<td>118.7503±1.4</td>
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<td>MWI-12</td>
<td>118.7503±1.2</td>
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<td>MWI-13</td>
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<td>MWI-14</td>
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<td>MWI-16</td>
<td>183.31±4.9</td>
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<td>183.31±3.4</td>
</tr>
<tr>
<td>MWI-18</td>
<td>183.31±2.0</td>
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</table>
Thank You – Any Questions

3MI Test Data Example